

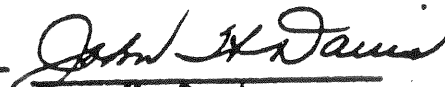
NORTH CAROLINA STATE HIGHWAY COMMISSION
Raleigh, N. C.

HANDBOOK OF DESIGN FOR
HIGHWAY SURFACE DRAINAGE STRUCTURES

Prepared by

Bridge Location & Hydrographic Department
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1973

Approved by -


John H. Davis
Chief Engineer &
Asst. Administrator

Section I - Administration and General Policies

100-General

- 100.01 The Bridge Location and Hydrographic Department is responsible for the field surveys and hydraulic design for all structures constructed by the Highway Commission. The work of the department is under the direction of the Hydrographic Engineer. His staff includes an assistant, approximately ten engineers specially trained and skilled in bridge location and drainage work, and the necessary number of engineering aides to comprise the field parties required to perform the work of the department.
- 100.02 This handbook is an outline of methods used by the Hydrographic Department of the N. C. State Highway Commission in preparing all drainage structures coming under its jurisdiction.
- 100.03 For a complete package, the following publications should be included as part of this handbook:
1. Hydraulic Engineering - Circular No. 11
 2. Hydraulic Engineering - Circular No. 12
 3. Hydraulic Engineering - Circular No. 13
 4. Hydraulic Design - Series
 - No. 1 - Hydraulics of Bridge Waterways.
 - No. 3 - Design Charts for Open Channel Flow.
 - No. 4 - Design of Roadside Drainage Channels.(Above available from Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402)
 5. Floods on Small Streams in N. C. - U. S. G. S. Circular 517.
 6. Drainage Areas at Selected Sites on Streams in N. C. - G. S. Open File Report.
- 100.04 By following the criteria and the methods outlined herein, sound and consistent design will be accomplished. It is expected that from time to time, revisions will be issued to parts of the handbook in order to upgrade the results consistent with advancing research and technology in the fields affecting highway and related drainage design.
- 100.05 Included in this section are general drainage policies of the Highway Commission for those who are unfamiliar or need refreshing. Necessarily, all circumstances cannot be covered, and for specific information on unusual circumstances, advice from the State Hydrographic Engineer's office should be obtained.

100.06 In general, bridges will be employed where discharge and velocity requires 300 sq. ft or more. Box culverts will be used when 60 sq. ft. or more are required and pipe and multiple pipe below this. It is emphasized that this is strictly empirical and has no bearing when site conditions, economy, or other considerations, dictate otherwise.

101-Pipe Culverts Materials

- 101.01 Pipe materials allowable are as those included in the specifications. In general, reinforced concrete is preferable when site conditions do not require other material. On projects, where design requires a large percentage of corrugated metal, it is usually preferable to use all corrugated metal. Where corrugated steel pipe is used, it is usually economical to use 3" x 1" corrugations on 36" and larger.
- 101.02 It is often desirable to compare the costs of more than one type structure to select the most desirable for economy and durability. When using metal pipe, it is usually desirable to require elongation where applicable for economy.
- 101.03 Usual practice is to specify half coated and paved corrugated metal, except in the coastal plain, where fully coated without paving, is generally specified.
- 101.04 Headwalls are used on pipes above 36" in diameter, usually on both ends, but always on the inlet. Flared end sections are used on smaller pipe.

102-Flood Plain Information

- 102.01 On all structures, where design discharge is more than 500 c.f.s., this will be shown on the plans along with the frequency and high water elevations.
- 102.02 When flood plains are encroached upon on streams of greater than 500 c.f.s. design discharge, the design flood profile will be shown with and without the encroachment.
- 102.03 When practical, flood plain locations will not be used; but when necessary, encroachment should be kept to a minimum.

103-Drainage Easements

- 103.01 Drainage easements, permanent and temporary, will be acquired as needed, as outlined in 103.05 in specific drainage policy.
- 103.02 Where permanent easements are required, sufficient information will be obtained so that the limits, grade, and cross section may be determined. The easement shall be of sufficient size to contain the spoil and provide working room for equipment.
- 103.03 When outlet drain maintenance is required and a permanent easement is not required, nor desirable, the work is accomplished under a permit of entry. The length of the cleanout and cross section of the proposed channel should be shown on the plans.
- 103.04 Where no work is to be performed, this shall be noted on the drainage survey with any applicable comment.
- 103.05 Where water is discharged from the right of way outside a natural drain or existing ditch, an easement is required for the necessary channel and construction operation to a natural drain. Where diversion of water is made to a natural drain or existing ditch which would increase the discharge considerably above its capacity, an easement is required to enlarge and improve the drain to a point where the increased discharge can be released without causing damage.
- 103.06 Where improvement to an existing drain is required for proper drainage and not covered in the paragraph above, a permanent drainage easement is not required. Even though the drain may be enlarged and deepened, if the property owner is informed of what is to be done and agrees in writing to allow entry onto his property for this work, this is all that is required. This should not be construed to mean that in all cases of this nature, a permit of entry only should be obtained. There will be instances where a permanent easement is desirable. Also, it should not be necessary to obtain written permit of entry on those drains which have previously been routinely maintained. Permission for this is implied until otherwise advised by the property owner.

104-Roadway Dams

- 104.01 It is the policy of the Division of Highways to discourage the location of roadways on dams. In those cases, where a definite advantage may be gained or a substantial savings in funds may be realized, the utilization of a dam for a roadway may be favorably considered.
- 104.02 Where it is determined that a dam will be utilized as a roadway, the following criteria must be met:
- A. When applicable, the dam must have certification from the N. C. Department of Natural and Economic Resources, pursuant to the "Dam Safety Law of 1967".
 - B. All pertinent data regarding the design of the embankment as an impoundment structure must be presented to the Division of Highways for review.
 - C. Top section must be roadway width for facility plus a minimum of 4'.
 - D. Guardrail will be provided on the impoundment side of the roadway.
 - E. Spillway will be designed to provide 2' of freeboard at the shoulder for an estimated 50-year frequency outflow as a minimum.
 - F. Means of draining the lake completely will be provided.
- 104.03 Design acceptance or approval by the Division of Highways is limited to the use of the dam as a roadway and is in no way intended as approval of the embankment as an impoundment structure.
- 104.04 Responsibility incurred by the Division of Highways when a section of roadway crossing a dam is accepted as a part of the state maintenance system is limited to maintenance of the roadway for highway purposes from shoulder point to shoulder point only. Responsibility for the impoundment, any damage that may result therefrom, and maintenance of the dam or appurtenances as may be required to preserve its integrity as a water impoundment structure, shall remain with the owner of the impoundment. Any such maintenance work will be subject to the provisions of G.S. 136-93.
- 104.05 Impoundment of water on highway right of way may be allowed under the following criteria:
- A. The impoundment does not adversely affect the right of way for highway purpose.
 - B. Adjustment, as required, flattening slopes, installing rip rap, and any others, shall be the responsibility of the encroaching party.

105-Subdivisions

- 105.01 When accepting streets for maintenance, where drainage check is required by the Hydrographic Department, the following information should be furnished for the review.
- A. Street layout and grades.
 - B. Typical Section.
 - C. Contour map (if available)
 - D. Pipe sizes and grades.
 - E. Drainage areas at each pipe or inlet.
 - F. Proposed easements.
 - G. Vicinity map.
- 105.02 The above information should be submitted prior to beginning of construction of the subdivisions, so that if any changes are recommended, these could be incorporated in the original construction, rather than having to go back and make adjustments.
- 105.03 In the case of higher type subdivisions where curb and gutter section will be used, details should be submitted showing proposed catch basins, manholes, etc., along with the grades of the storm sewer system.
- 105.04 Where storm sewer systems are used, the design for the collector system should be for the 10-year frequency storm; and for cross drainage, the 25-year frequency storm.
- 105.05 With the above information furnished the Hydrographic Department, the check of the design of the proposed drainage system can be made at a minimum cost to the Highway Commission.
- 105.06 Where roads and streets built by others now exist on the system, the State Highway Commission's responsibility for the drainage system installed by the developer does not exceed the right of way, or easement limits accepted by the State Highway Commission. The acceptance of the streets onto the state system does not include drainage easements outside the right of way unless specifically stated that those easements so designated by the Commission are included in the acceptance.
- 105.07 Where request for additions to the System arise on roads and streets built by others, the request shall not be granted until the drainage installations have been inspected and approved by a representative of

105-Subdivisions

105.07 (Continued)

the State Highway Commission. The representative shall be the Division Engineer or his appointed representative. If desired, or if special treatment is needed, a review by the Hydrographic Department should be requested. If structures other than pipe installations are included, they shall be approved by the Asst. Chief Engineer-Bridges.

110-General Drainage Policy

- 110.01 Right of Parties - Civil law in North Carolina generally provides that lower lands are subservient to upper lands for the natural drainage flowing to it. This law applies to the privately owned land, as well as State Highway Commission rights of way. It is the policy of the State Highway Commission to accept this provision of the law by providing sufficient drainage ways, so as not to impede natural flows to the extent that upper lands are damaged thereby.
- 110.02 Acceleration - In the rapidly expanding economy of the State, much development is taking place. This development causes increased peak flow by increasing impervious areas, more rapid overland flow, and providing more hydraulically efficient channels. Civil law generally provides that this acceleration of flow also becomes the natural burden of the lower lands, if the acceleration is the result of good husbandry in the use of the upper lands. It is the policy of the State Highway Commission to provide for this accelerated flow reaching its right of way by providing sufficient drainage ways therethrough. Conversely, it is the policy of the State Highway Commission to deny responsibility to lower properties for accelerated flow caused by improvements in its rights of way, unless distinctly and solely determined to be detrimental.
- 110.03 Diversions - Diversions are defined as the act of draining surface waters from an area outside the natural boundaries of a watershed into the drain serving the watershed. Civil law provides that parties creating a diversion of water shall be liable for all damage caused by the diversion. Note that the act of diversion is not prohibited, but it does create liability where damage occurs. It is the policy of the State Highway Commission to so design and maintain its road system, so that no diversions are created thereby, insofar as is practicable from good engineering practice. Any person(s) creating a diversion into any highway drain shall do so only after receiving written permission from the Chief Engineer. Permission will be granted only after it has been determined that the additional water can be properly handled without damage, that any adjustments required to the highway drainage system will be borne by the requester, that not granting of the permission will be a distinct burden to the requester and that in general, the diversion will be in the public interest. The Chief Engineer

110-General Drainage Policy

- 110.03 (Continued)
shall provide that the State Highway Commission is properly indemnified from any claim for damage which may arise from such diversions. It is generally desirable that the State Highway Commission not become a party to such diversions, unless to refuse would create a considerable and real hardship to the party(ies) requesting such permission.
- 110.04 It is the policy of the State Highway Commission to provide for each natural drain traversing its right of way, and not combine several drains and place in a single structure, except where good engineering judgment dictates otherwise, and thorough investigation of the results which may arise from such combining and diversions of these drains has determined that the best interest of the State Highway Commission and public will be served.
- 110.05 Obstructions - Civil law provides that the lower subservient land shall accept the natural flow from upper lands without artificial obstruction thereto detrimental to the upper land. Statute Law (GS 136-92) provides that anyone obstructing any drains along or leading from any public road is guilty of a misdemeanor.
- 110.06 It is the policy of the State Highway Commission that when a drain is blocked below the highway, which is detrimental to highway drainage, if from natural causes, the State Highway Commission will take necessary measures to remove the block or obstruction. Where the block is caused by wrongful acts of others, it is the policy of the State Highway Commission to take whatever recourse deemed advisable and necessary to cause the party(ies) responsible to remove the block. Where a block is created downstream of a highway, whether natural or artificial, and is of no consequence to the State Highway Commission, it is the policy to remain neutral in causing its removal.
- 110.07 It is not the responsibility of the State Highway Commission to eliminate flooding on private property which is not attributable to acts of the Commission, or its representative.
- 110.08 Restoring Existing Drains - In the design of highways where existing drains will be crossed, interrupted, or destroyed, it is the policy of the State Highway Commission to replace in kind or better, or to pay for replacement of all such drains.

110-General Drainage Policy
(Continued)

110.09 While it is the responsibility of the State Highway Commission to provide for adequate drainage for the construction of roads and modern highways, it is not the policy nor the responsibility to provide improved drainage for the general area traversed by such road, unless incidental to the drainage of the road or highway itself.

110.10 It is the policy of the State Highway Commission to make sufficient investigation outside of right of way to insure that the design of the highway drainage facilities will not be detrimental to private property, insofar as is feasible.

When highways are constructed for the embankment to be used as a dam, it is the policy of the State Highway Commission to require the party(ies) requesting the use of the embankment as a dam to bear all additional cost incidental to making the embankment serve as a dam. In general, this practice will be avoided except where shown to be in the interest of the public.

110.20 Maintenance - Maintenance of drains along the right of way, and those outside, which are the responsibility of the State Highway Commission shall be done with continuing respect for adjacent property. Any changes from established drainage patterns will only be made when it is determined that the best interest of the State Highway Commission, and all affected property owners are served.

110.21 Established pipe crossings will be maintained and request to eliminate any pipe should have approval by the State Hydrographic Engineer before permission is granted.

110.22 In general, outlet ditches will be maintained for a sufficient distance below the road to provide adequate drainage therefor. On large outlets serving considerable area outside the right of way, the maintenance should be done on a cooperative basis, with the benefited properties bearing their proportionate share. Shares will, in general, be based on proportion of runoff from the areas served by the outlet.

110.23 Drainage structures under the roadway will be kept open at all times. It is the responsibility of the District Engineer to have periodic inspections made as necessary to insure that drainage structures do not become blocked or clogged.

120-Drainage and Flood Control Projects

- 120.01 When any drainage district or flood control project makes necessary the revision, modification, replacement, or construction of any drainage structure on any road maintained by the State Highway Commission, the cost of such revision, modification, replacement, or construction of such structure shall be paid as follows:
- 120.02 Where the drainage district or flood project requires the construction of a new structure where one has not previously existed, the entire cost of such structure, constructed with Standard State Highway Commission designs, shall be borne by the drainage district or flood control project.
- 120.03 Where an existing drainage structure has to be replaced, the cost of replacing the existing structure with a structure of like design, width, load bearing capacity, and life expectancy shall be borne by the drainage district or flood control project. Should it be deemed necessary or advisable by the State Highway Commission, in replacing the existing structure, to construct one of more modern design, or of greater width, or of a higher load bearing capacity, the cost of such and similar improvements shall be borne by the State Highway Commission.
- 120.04 Where an existing drainage structure has to be modified, revised, or extended due to the deepening or widening of the waterway, approaching, leaving, or passing under or through the drainage structure, such modification, revision or extension shall be borne by the drainage district or flood control project, provided that such modification, revision, or extension, does not significantly improve the general design features, or does not significantly increase the width load bearing capacity, or life expectancy of the structure. Should it be deemed necessary or advisable by the State Highway Commission in modifying, revising, or extending the existing design features, the width, load bearing capacity, or life expectancy of the structure, the additional cost of such improvements shall be borne by the State Highway Commission.

120-Drainage and Flood Control Projects
(Continued)

- 120.05 Where a lake or reservoir floods a road or drainage structure causing the relocation of such road or drainage structure, the cost of road relocations to be charged to the water project shall be the difference between the cost of constructing the highway to modern highway design standards on the new location or elevation resulting from the water project and the cost of reconstructing the existing highway to the same modern standards without regard to the water project. Modern highway design standards should be based on a projection of traffic conditions for not more than twenty years in the future.
- 120.06 Any direct benefits to the State Highway Commission due to the improvement of the drainage structure, or due to the work proposed by the drainage district will be paid for by the State Highway Commission. The maximum benefit to be paid by the Commission under the provisions of this item will be limited to the cost of the highway drainage structure involved. Such direct benefits to be determined by conference between representatives for the Highway Commission and the officials of the drainage district.
- 120.07 The adjustments of pipe culverts will be in accordance with the policy for other pipe crossings.

130-Adjustments to Pipe Culverts

- 130.01 Where the elevation of the flow line of a pipe under a highway is not low enough to take care of drainage, it shall be the responsibility of the State Highway Commission (without charge to the property owner) to lower the pipe, or otherwise provide needed lower drainage under the highway and within the limits of the right of way.
- 130.02 When the lowering of the drainage causes an increase in the amount of water, due to diversions to serve larger areas than before, requiring a larger size pipe, the property owner will be required to furnish the pipe delivered to the site, to be installed by the State Highway Commission.
- 130.03 When a new pipe crossing is requested, if the pipe crossing is required for proper highway drainage, the full cost will be borne by the State Highway Commission. Where the new crossing is not a requirement, but sufficiently beneficial to highway drainage, the State Highway Commission will make the installation, provided the property owner furnish the pipe delivered to the site. Where the new installation is of doubtful, or no benefit to highway drainage, the property owner will bear the entire cost of the installation.
- 130.04 When new drives are constructed entering the highway, the property owner will furnish, delivered to the site, the amount, type, and size pipe designated by the State Highway Commission, to be installed by the State Highway Commission.
- 130.05 In general, the conditions referred to above include pipe installations where the property owner, in order to provide adequate drainage has lowered the flow line of the inlet and the outlet ditch to a pipe culvert that crosses a highway; where the lowered outlet ditch has satisfactory fall and does not divert water from the natural drainage; where there is reason to believe it is practical to maintain the outfall; and where the benefit to the property affected equals or exceeds the cost of lowering the pipe.
- 130.06 It is not the policy of the Highway Commission to pipe inlet or outlet drains, natural or artificial, outside the right of way, which existed as open drains prior to existence of the highway. Where the property owner wishes to enclose an inlet or outlet, the Highway Commission may install the pipe adjacent to the right of way if justified

130-Adjustments to Pipe Culverts
(Continued)

130.06 (Cont'd.)

by reason of reduced maintenance, safety or aesthetics if the pipe is furnished at the site by the property owner. This does not apply to the development of commercial property.

140-Alterations on Right of Way

140.01 Alterations to Box Culverts - No alterations of, nor additions to any box culvert on the highway system shall be allowed without written permission from the Assistant Chief Engineer-Bridges, or his authorized representative.

All requests for alteration of, or additions to, box culverts shall be made in writing to the Division Engineer. Six prints shall be furnished showing in detail the location and nature of the proposed work. The prints shall show sufficient detail so that they may be used as construction drawings. The proposed alteration shall be within good engineering construction and hydraulic design. The Division Engineer shall forward one of these drawings to the Assistant Chief Engineer-Bridges, with his recommendations. After any required revisions and upon approval of the plans by the Assistant Chief Engineer-Bridges, the request shall be returned to the Division Engineer for preparation and execution of the Encroachment Contract.

140.02 Alterations to Pipe Culverts - No alteration, extension nor addition of appurtenance to any pipe culvert shall be allowed on highway right of way without the written consent of the Division Engineer. or his authorized representative.

0.03 All requests for alteration, extension or addition of appurtenance to any pipe culvert shall be made in writing to the Division Engineer. Six prints shall be furnished showing the location and detail of the proposed work. The print shall include arrows indicating the direction of flow, and approximate acreage drained by the pipe and size and type of the existing pipe. If appurtenances are involved, the type construction shall be shown. The approximate height from invert to inlet shall be shown when catch basins are proposed. Where only minor drainage alterations are involved, the Division Engineer will approve the encroachment. If other than minor drainage alterations are involved, the Division Engineer shall submit one drawing with recommendations to the State Hydrographic Engineer for approval. Upon approval by the State Hydrographic Engineer, the request shall be returned to the Division Engineer for preparation and execution of the Encroachment Contract. (Any request for alteration to pipe culverts may be submitted to the State Hydrographic Engineer, if the Division Engineer deems it desirable.)

Section II - Hydrology

200-General

- 200.01 Hydrology in highway drainage design concerns itself with the determination of discharges to be used for application of hydraulic theory to provide adequate capacity for project structures.
- 200.02 There are many ways of approaching this determination. These range from empirical to so-called rational methods; applications of rainfall data; and statistical analysis of stream gage data.
- 200.03 This section presents the methods employed by the Hydrographic Department to determine discharges of the desired frequency for structure hydraulic design.

201-Site Hydrology

- 201.01 The first most significant factor affecting runoff is the size of the catchment basin above the site under consideration, referred to simply as the drainage area.
- 201.02 Drainage areas may be obtained from several sources. The larger areas may be obtained from several sources. Many are listed in the Geological Survey open file report "Drainage Areas at Selected Sites on Streams in North Carolina." If the exact site is not listed, usually one close enough so that only small adjustment is necessary may be found.
- 201.03 For smaller areas, aerial photography is available in the Planning and Research Cartographic section. Steroscopic coverage is available for the entire State, with the exception of Dare County.
- 201.04 Many times it will be desirable or necessary to determine drainage areas by field reconnaissance.
- 201.05 By whatever method the drainage area is determined, during the field survey, the general area should be reconnoitered to get sufficient information of the features which will affect runoff.
- 201.06 On those drainage areas of less than 1000 acres, during the determination of size and the reconnaissance the length of the area (L) must be determined (approximately). This is defined as the distance from the structure site to the farthest divide following the approximate center of the area, or principal thalweg.
- 201.07 Also, at this time, on those areas less than 1000 acres, the determination of the type culture which would affect runoff is made. On rural watersheds, this would be the percent woodland or forest cover; on urban watersheds, this would be the type and relative density of development.
- 201.08 For areas above 100 acres, only the area is required as other factors affecting runoff are homogeneous enough so that the hydrologic contour and drainage area are the only significant variable.
- 201.09 From Chart C200.1 "Map of Hydrologic Contours", determine the hydrologic contour by location of the structure site. Interpolate to 0.5 contour interval.

202-Site Discharge

- 202.01 If the area is rural and larger than 1000 acres, enter Chart C200.2 with drainage area and hydrologic contour and read discharge. If other than Q50 is required, apply frequency correction factor shown on the chart.
- 202.02 If the area is rural and less than 1000 acres determine W/L ratio ($W/L = A/L^2$) and the percent forested cover. Enter appropriate Charts Nos. C200.4 and C200.5 to determine correction factors to be applied to value from Chart C200.1. The combination of the two corrections should not exceed the limits of ~~0.6~~ and ~~2.0~~.
0.
- 202.03 If the area is urban and less than 125 acres, enter Chart C200.3 with drainage area and hydrologic contour and determine chart value for Q10. If other frequency is desired, apply frequency correction factor shown on the chart.
- 202.04 Deleted 10-21-77
- 202.05 From instruction in paragraph 201.07, determine if density of development correction is necessary. Apply correction factor from inset density correction factor.
- 202.06 If the urban area is greater than 125 acres, utilize procedure described in section 202A.
- 202.07 If the area is greater than 50 sq. mi., use method described in U.S.G.S. publication "Water Resources Investigations 76-17".
- 202.08 Gaging station records should be checked for all stream crossings. Where records are available, an analysis should be made and an evaluation of results obtained to be compared with those obtained from the runoff charts.

203- Adjustment of Discharge

- 203.01 In those areas, particularly in the potentially low runoff areas in the coastal plain, where channelization has occurred, caution must be used in applying the hydrologic contour. It is suggested that a contour of 0.5 to 1.0 above that taken from Chart C200.1 be used, depending on the intensity of channel work.
- 203.02 In the eastern coastal plain, where the drainage area consists of large swamp areas with large storage volumes, discharges may be reduced as much as 15-20% below the curve value.
- 203.03 On any stream, where flood control structures or works are in place or under design, the effect of the works should be determined and the structure designed for the reduced discharge.

202A--Urban Hydrology

The following procedure will be utilized in estimating peak discharges for ungaged urbanized watersheds in excess of 125 acres. For smaller watersheds highway chart C 200.3, the rational method or other appropriate methods will be utilized.

This as any hydrological method must be applied with good judgement and the engineer is encouraged to compare the result with other methods and historical occurrence and make adjustments when deemed appropriate.

This procedure is an adaptation of the procedure presented in "Techniques for Estimating Flood Hydrographs for Ungaged Urban Watersheds" published as Open-File Report 82-365 by the U.S. Geological Survey.

1. Determine the size of the drainage area and compute the equivalent rural discharge (RQ)
2. Divide the watershed into approximate equal thirds. (Upper, middle, lower)
3. Compute the basin development factor (BDF - value of 0-12) for each third of the watershed. Four aspects of the drainage system are evaluated and assigned a code of 1 or 0. This evaluation must include consideration for planned or predicted future development.
 - a. Channel Improvements
Has a prevalent amount ($\geq 50\%$) of the main and principal tributary channels been or expected to be subjected to improvements such as straightening, enlarging, deepening, or clearing. If so assign a value of 1, if not 0.
 - b. Channel Linings
Has a prevalent amount ($\geq 50\%$) of the main and principal tributary channels been or expected to be lined with an impervious material. If so assign a value of 1, if not 0.
 - c. Storm Drains
Has a prevalent amount ($\geq 50\%$) of the secondary tributaries been enclosed in drainage structures such as pipes. If so assign a value of 1, if not 0.
 - d. Curb and Gutter Streets
If more than 50% of the subarea (third) is urbanized and more than 50 percent of the streets and highways are curbed and guttered then assign a value of 1, if not 0.

Total the values for the three subareas to establish the BDF.

4. Compute the urban peak discharge using the following appropriate equation:

$$UQ_2 = 13.2A^{.21} (13-BDF)^{-.43} RQ_2 .73$$

$$UQ_5 = 10.6A^{.17} (13-BDF)^{-.39} RQ_5 .78$$

$$UQ_{10} = 9.51A^{.16} (13-BDF)^{-.36} RQ_{10} .79$$

$$UQ_{25} = 8.68A^{.15} (13-BDF)^{-.34} RQ_{25} .80$$

$$UQ_{50} = 8.04A^{.15} (13-BDF)^{-.32} RQ_{50} .81$$

$$UQ_{100} = 7.70A^{.15} (13-BDF)^{-.32} RQ_{100} .82$$

Where UQ = Urban peak discharge
 A = Watershed area in Square Miles
 BDF = Basin Development Factor
 RQ = Equivalent rural discharge

204-Rational Method

- 204.01 For those who prefer, and where the foregoing may not apply, the Rational Formula is acceptable for computing runoff. This method is well enough known so as not to require details here.
- 204.02 In applying this method, the minimum time of concentration shall be 15 minutes and the maximum weighted 'C' for areas over 5 acres shall not exceed 0.8.
- 204.03 Weather bureau curves for representative areas for intensity, duration, and frequency, are included herein, as charts C200.7, C200.8, and C200.9. Interpolation between stations is allowed. Weather Bureau technical paper No. 40 may be used to construct these curves for other areas of desired.
- 204.04 Further discussions, 'C' value tabulations, and time of concentration nomographs are included in "Drainage of Highway Pavements" and "Design of Roadside Drainage Channels."

205-Conclusions

- 205.01 Determining reasonable design discharges of the desired frequencies is one of the most difficult and perplexing tasks faced by Highway Drainage Engineers. The method used by the North Carolina State Highway Commission has been greatly simplified by a combination of experience in North Carolina drainage work and utilization of gage data of varying lengths of record. While we have no argument with other methods, it is felt that the use of this method gives consistently good results, even when used by engineers with limited experience in hydrological work. The method is subject to refinements and the engineer using it is encouraged to adjust results within his experience and judgment. Certainly when a gage record of significant length is available on the stream on which the structure is to be placed, this should be used in lieu of the curves. Also, the credenda of the performance on an existing structure should not be ignored.
- 205.02 The designer of drainage structures should use all information available in determining runoff and will never be amiss to compare the results of several methods and select the result which, in his judgment, is most acceptable.

Section III - Hydraulics

300-General

- 300.01 After the discharge of the project design frequency has been determined, it then is necessary to determine by hydraulic principles the structure required to adequately pass the discharge within controls established for the site.
- 300.02 The site controls will consist of limits of headwater velocities, tailwater, scour, and other hydraulic considerations, as well as structural requirements.
- 300.03 Methods of hydraulic design used by the department are generally standard for highway hydraulic design. It is expected that users of this handbook will be familiar with basic hydraulic principles, or will have references adequately covering the subject. References mentioned in the handbook are available (for loan) from the Hydrographic Engineer's office.
- 300.04 Slide rule accuracy is sufficient for all hydraulic computations.
- 300.05 Calculations should be neatly made and become part of project file.

301-General Criteria

301.01 Hydraulic design for roadway ditches:

1. Design frequency - see Table T300.1.
2. Design Q - Computations
S.H.C. or Rational Method (see Charts C400.1 and C400.2)
3. Hydraulic design - Manning's Formula
4. Allowable velocities
Up to 4 fps on grassed linings - dependent on soil.
Pave to contain 5-year discharge for over 4 fps.
5. Minimum grade desirable - 0.3%.
6. Type of ditch inlet - Standard to bed determined
by State Design Engineer.

301.02 Hydraulic Design for Median Ditches:

1. Design frequency - see Table T300.1.
2. Design Q - Charts Nos. C400.3 and C400.4, or
Rational Method.
3. Hydraulic design, Manning's Formula
4. Allowable velocities - same as roadway ditches
5. Minimum grade desirable - 0.3%.
6. Maximum depth of flow - 0.5' below shoulder point.
7. Maximum inlet spacing 800' (350' on closed system).

301.03 Hydraulic Design for Roadway Culverts:

1. Design frequency - see Table No. T300.1.
2. Design Q - S.H. C. or Rational Method.
3. Hydraulic Design - Hydraulic Engineering Circular
No. 5.
4. Headwater - Generally HW/D of 1.2 or 1.5 ft. below
shoulder point, whichever is lower. Determination
should be made that resultant ponding will not be
detrimental to adjacent property.
5. Outlet velocities in excess of 10 fps. will require
erosion control at the outlet. In many cases, special
outlet structures (stilling basins) will be required.
When velocities exceed 15 fps., these will be considered.

301.04 Hydraulic Design for Curbed Pavement:

1. Design frequency - Table T300.1 for gutters.
2. Design discharge - S.H.C. or Rational Method.
3. Hydraulic design - see Charts C400.7 and C400.8.
4. Maximum depth of flow 0.5' at curb of 6' spread into
thru traffic lane.

301.04 Curbed pavement: (continued)

5. Inlet - use N. C. standard 840.1 with type "A" grate on high traffic facility and type "D" on residential streets. The standard 840.06 is used only for special conditions where large quantities of flow at high velocities are required to be intercepted.

301.05 Hydraulic Design for Storm Sewers:

1. Design frequencies - see Table T300.1.
2. Design Q - S.H.C. or Rational Method.
3. Hydraulic design - Hydraulic Engineering Circular No. 5. HW/D should not exceed 0.5' below grate elevation. Where more accuracy in critical design areas are required, the method in "Pressure Changes at Storm Drain Junctions" may be employed.
4. Design calculations should be recorded on tabular form for review and future reference. See C400.9 in design aides section for example.
5. Pipe profiles shall be developed and all known underground utilities shown thereon. Conflicts should be kept at a minimum, but where unavoidable, proper provision shall be made, such as special junction boxes or manholes.
6. When pipe sizes change through a box or manhole, the crown of the pipes shall be aligned vertically where available fall permits.

	Interstate	Primary	Major Secondary	Minor Secondary	City Thoroughfare	City Street
Bridge	50*	50*	50	25	50	25
Box Culvert	50*	50*	50	25	50	25
Pipe Culvert	50	50	50	25	25	25
Roadway Ditch	5	5	5	3	5	3
Median Drainage System	10	10	10	—	—	—
Storm Drain	10	10	10	—	10	10
Sump Drain	50*	50*	25	25	25	25
Gutter	5	5	5	3	5	3

* Effect of 100-year flood to be checked and adjustments to design flood made where deemed necessary.

TABLE OF PROJECT HYDRAULIC
DESIGN FREQUENCIES